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Experiment 3: Reflection

Required Equipment from Basic Optics System
Light Source
Mirror from Ray Optics Kit
Other Required Equipment
Drawing compass
Protractor
Metric ruler
White paper

Purpose

In this experiment, you will study how rays are reflected from different types of mirrors. You will measure the focal length and determine the radius of curvature of a concave mirror and a convex mirror.

Part 1: Plane Mirror

Procedure

1. Place the light source in ray-box mode on a blank sheet of white paper. Turn the wheel to select a single ray.

2. Place the mirror on the paper. Position the plane (flat) surface of the mirror in the path of the incident ray at an angle that allows you to clearly see the incident and reflected rays.

3. On the paper, trace and label the surface of the plane mirror and the incident and reflected rays. Indicate the incoming and the outgoing rays with arrows in the appropriate directions.

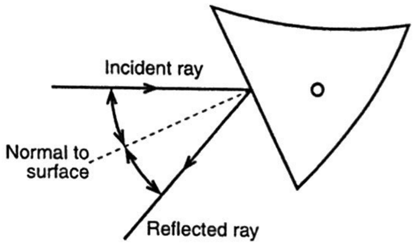

Figure 3.1

4. Remove the light source and mirror from the paper. On the paper, draw the normal to the surface (as in Figure 3.1).

5. Measure the angle of incidence and the angle of reflection. Measure these angles from the normal. Record the angles in the first row Table 3.1.

6. Repeat steps 1–5 with a different angle of incidence. Repeat the procedure again to complete Table 3.1 with three different angles of incidence.

Table 3.1: Plane Mirror Results

Angle of Incidence	Angle of Reflection
29°	29°
9°	9°
15°	15°

7. Turn the wheel on the light source to select the three primary color rays. Shine the colored rays at an angle to the plane mirror. Mark the position of the surface of the plane mirror and trace the incident and reflected rays. Indicate the colors of

the incoming and the outgoing rays and mark them with arrows in the appropriate directions.

Questions

1. What is the relationship between the angles of incidence and reflection?
   They are equal
2. Are the three colored rays reversed left-to-right by the plane mirror?
   They are not reversed by the plane mirror

Part 2: Cylindrical Mirrors

Theory

A concave cylindrical mirror focuses incoming parallel rays at its focal point. The focal length (f) is the distance from the focal point to the center of the mirror surface. The radius of curvature (R) of the mirror is twice the focal length. See Figure 3.2.

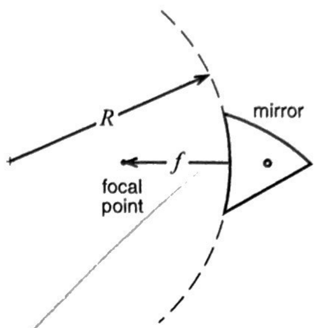

Figure 3.2

Procedure

1. Turn the wheel on the light source to select five parallel rays. Shine the rays straight into the concave mirror so that the light is reflected back toward the ray box (see Figure 3.3). Trace the surface of the mirror and the incident and reflected rays. Indicate the incoming and the outgoing rays with arrows in the appropriate directions. (You can now remove the light source and mirror from the paper.)

2. The place where the five reflected rays cross each other is the focal point of the mirror. Mark the focal point.

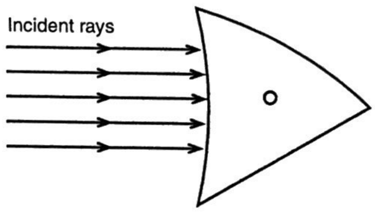

Figure 3.3

3. Measure the focal length from the center of the concave mirror surface (where the middle ray hit the mirror) to the focal point. Record the result in Table 3.2.

4. Use a compass to draw a circle that matches the curvature of the mirror (you will have to make several tries with the compass set to different widths before you find the right one). Measure the radius of curvature and record it in Table 3.2.

5. Repeat steps 1–4 for the convex mirror. Note that in step 3, the reflected rays will diverge, and they will not cross. Use a ruler to extend the reflected rays back behind the mirror's surface. The focal point is where these extended rays cross.

Table 3.2: Cylindrical Mirror Results

	Concave Mirror	Convex Mirror
Focal Length		
Radius of Curvature (determined using compass)		

Questions

1. What is the relationship between the focal length of a cylindrical mirror and its radius of curvature? Do your results confirm your answer?

2. What is the radius of curvature of a plane mirror?

Experiment 4: Snell's Law

Required Equipment from Basic Optics System

Light Source

Trapezoid from Ray Optics Kit

Other Required Equipment

Protractor

White paper

Purpose

The purpose of this experiment is to determine the index of refraction of the acrylic trapezoid. For rays entering the trapezoid, you will measure the angles of incidence and refraction and use Snell's Law to calculate the index of refraction.

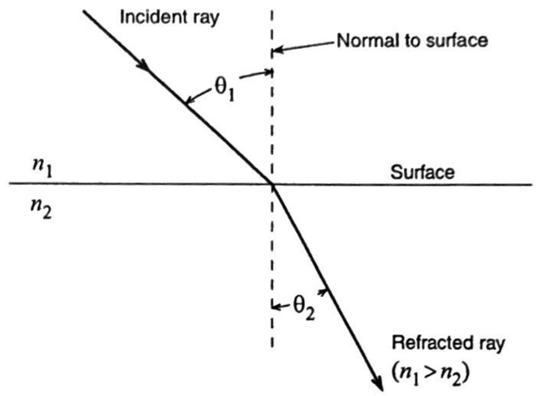

Figure 4.1

Theory

For light crossing the boundary between two transparent materials, Snell's Law states

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

where θ_1 is the angle of incidence, θ_2 is the angle of refraction, and n_1 and n_2 are the respective indices of refraction of the materials (see Figure 4.1).

Procedure

1. Place the light source in ray-box mode on a sheet of white paper. Turn the wheel to select a single ray.

2. Place the trapezoid on the paper and position it so the ray passes through the parallel sides as shown in Figure 4.2.

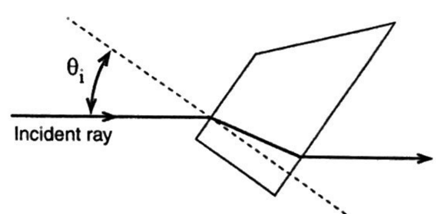

Figure 4.2

3. Mark the position of the parallel surfaces of the trapezoid and trace the incident and transmitted rays. Indicate the incoming and the outgoing rays with arrows in the appropriate directions. Carefully mark where the rays enter and leave the trapezoid.

4. Remove the trapezoid and draw a line on the paper connecting the points where the rays entered and left the trapezoid. This line represents the ray inside the trapezoid.

5. Choose either the point where the ray enters the trapezoid or the point where the ray leaves the trapezoid. At this point, draw the normal to the surface.

6. Measure the angle of incidence (θ_i) and the angle of refraction with a protractor. Both of these angles should be measured from the normal. Record the angles in the first row of Table 4.1.

7. On a new sheet of paper, repeat steps 2–6 with a different angle of incidence. Repeat these steps again with a third angle of incidence. The first two columns of Table 4.1 should now be filled.

$N_1 = 1$

$N_1 \sin\theta = N_2 \sin\theta$

$N_2 = \frac{N_1 \sin\theta_1}{\sin\theta_2}$

θ_1 θ_2

Table 4.1: Data and Results

Angle of Incidence	Angle of Refraction	Calculated Index of refraction of acrylic
[illegible]	16°	1.81
13°	6°	2.15
41°	30°	1.31
		Average: 1.75

Analysis

$\left|\frac{1.75-1.5}{1.5}\right| \times 100$

17.15%

1. For each row of Table 4.1, use Snell's Law to calculate the index of refraction, assuming the index of refraction of air is 1.0.

2. Average the three values of the index of refraction. Compare the average to the accepted value ($n = 1.5$) by calculating the percent difference.

Question

What is the angle of the ray that leaves the trapezoid relative to the ray that enters it?

The angle going in is the same as the angle going out of the trapezoid.

Experiment 5: Total Internal Reflection

Required Equipment from Basic Optics System
Light Source
Trapezoid from Ray Optics Kit

Other Required Equipment
Protractor
White paper

Purpose

In this experiment, you will determine the critical angle at which total internal reflection occurs in the acrylic trapezoid and confirm your result using Snell's Law.

Theory

For light crossing the boundary between two transparent materials, Snell's Law states

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

where θ_1 is the angle of incidence, θ_2 is the angle of refraction, and n_1 and n_2 are the respective indices of refraction of the materials (see Figure 5.1).

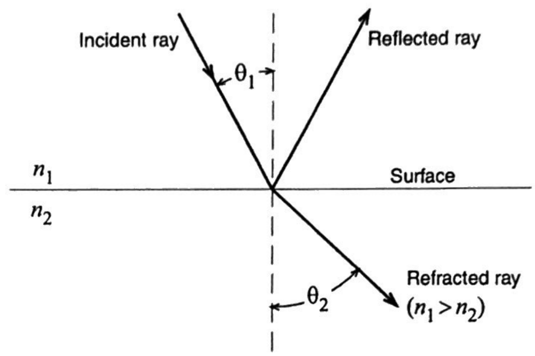

Figure 5.1

In this experiment, you will study a ray as it passes *out* of the trapezoid, from acrylic ($n = 1.5$) to air ($n_{air} = 1$).

If the incident angle (θ_1) is greater than the critical angle (θ_c), there is no refracted ray and total internal reflection occurs. If $\theta_1 = \theta_c$, the angle of the refracted ray (θ_2) is 90°, as in Figure 5.2.

In this case, Snell's Law states:

$$n \sin \theta_c = 1 \sin 90°$$

Solving for the sine of critical angle gives:

$$\sin \theta_c = \frac{1}{n}$$

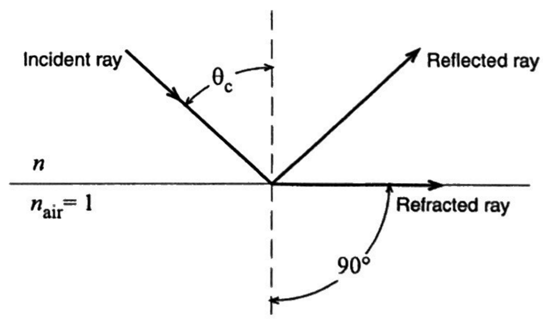

Figure 5.2

Procedure

1. Place the light source in ray-box mode on a sheet of white paper. Turn the wheel to select a single ray.

2. Position the trapezoid as shown in Figure 5.3, with the ray entering the trapezoid at least 2 cm from the tip.

3. Rotate the trapezoid until the emerging ray just barely disappears. Just as it disappears, the ray separates into colors. The trapezoid is correctly positioned if the red has just disappeared.

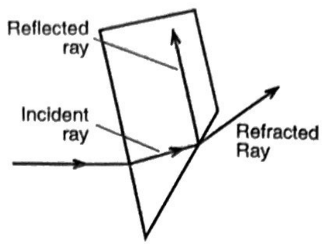

Figure 5.3

4. Mark the surfaces of the trapezoid. Mark exactly the point on the surface where the ray is internally reflected. Also mark the entrance point of the incident ray and the exit point of the reflected ray.

5. Remove the trapezoid and draw the rays that are incident upon and reflected from the inside surface of the trapezoid. See Figure 5.4. Measure the angle between these rays using a protractor. (Extend these rays to make the protractor easier to use.) Note that this angle is twice the critical angle because the angle of incidence equals the angle of reflection. Record the critical angle here:

   θ_c = 41.6° (experimental)

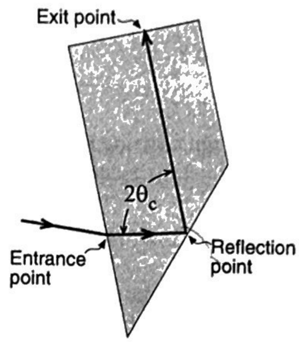

Figure 5.4

6. Calculate the critical angle using Snell's Law and the given index of refraction for Acrylic (n = 1.5). Record the theoretical value here:

   θ_c = 41.8° (theoretical)

   $\sin\theta_c = \frac{1}{n}$

   $\theta_c = \sin^{-1}\left(\frac{1}{n}\right)$

7. Calculate the percent difference between the measured and theoretical values:

   % difference = 0.7%

   $\left(\frac{41.8-41.5}{41.8}\right)\times 100$

Questions

1. How does the brightness of the internally reflected ray change when the incident angle changes from less than θ_c to greater than θ_c? It gets brighter

2. Is the critical angle greater for red light or violet light? What does this tell you about the index of refraction?

   Blue dissapears first